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ORIGINAL ARTICLE

An Assessment of the Potential, Suitability and Sustainability of the Sand Mining Site in the Kemaman River Basin, Terengganu Using Acoustic Doppler Current Profiler

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Abstract

Sand mining from the catchment basin for building is a worldwide issue. The increasing demand for sand in the construction industry has led sand suppliers to look for alternative methods by which they can obtain source of sand from the riverbed. Floodplain and river slabs can be used as new sources of sand mining. In Sungai Kemaman, during September until March a high precipitation can cause high flow in river. This high flow can cause riverbank erosion which leads to instability of river. Therefore, river erosion can probably be reduced by identifying the potential area for sand mining. This research was conducted to analyse sand capability on floodplain and riverbed by integrating resistivity method and sediment transport loads using Acoustic Doppler Current Profiler (ADCP). Resistivity survey is used in determining the availability of potential soil at the study area and the equipment could measure subsurface profile up to 80 meters depth. Meanwhile, ADCP survey is utilized to make river profiler in term of velocity meshes and riverbed depth. The primary data collected was from 20 January 2014 to 19 February 2014. The findings found that the samples trapped in the Helly-Smith grabber were majority of the samples consisted more than 93% of gravel and sand materials and from the resistivity analysis, it is verified that the surrounding materials along the Sungai Kemaman is sandy material and high potential of the sand mining site.

Keywords: Sand mining, Sungai Kemaman, Sediment, River bed, Erosion

Introduction

Unlawful sand mining has several physical, biological and socio-environmental effects on river basins. In addition, the extraction of this granular material is inevitable since the survival of the building industry relies heavily on it. In rivers, standard grade sand occurs in several sources, for instance the active canals, floodplains, and river terraces (Padmalal & Maya, 2014). The river island (any exposed land surrounded by river water) will reduce the hydraulic performance of the river (Teo et al., 2017; Al-Ansari et al., 2015). This is because river islands will affect the morphology of the river, which decreases the flood capacity of the river. Thus, removing sand from river islands can increase the hydraulic performance of the river and control the erosion of the river (Ladson & Judd, 2014; Saleh et al., 2017).

Meanwhile, Padmalal & Maya (2014) also found that the river island along some large rivers can be a new source of sand and gravel. This river bed can be extracted without severe damage to the river if proper management of sand extraction. Many local researchers have conducted the studies in exploring the activities of sand mining at Peninsular Malaysia. Previous study on sediment transport and sand mining activities has been published by local and worldwide researchers discussed on the characteristic of sediments, sand mining effects, causes and concerns, optimal sand removal capacity, flow of river and its effect on the bed sediment and environmental impact of soil and sand mining (Arun et al., 2019; Ding & Huang, 2017; Saleh et al., 2017, 2018; Teo et al., 2017; M. Naveen Saviour, 2012; Ashraf et al., 2011; Villatoro et al., 2010).

Based on that, most of researchers proved that sand mining can be done by various method. Therefore, it is important to apply a proper management to control excessive sand mining relating to the safety of worker and machine (Saleh et al., 2017). Before starting the extraction, the sand mining operator needs to determine the suitable machine to be used to extract the sand on riverbed. River bed material can have a great impact to the river performance (Ghani et al., 2011). This research was conducted to analyse sand capability on floodplain and riverbed by integrating resistivity method and sediment transport loads using Acoustic Doppler Current Profiler (ADCP).

Materials and Methods

Site Description

Site area of the project is situated at Sungai Kemaman Basin, Terengganu as shown in Figure 1 and 2. Sungai Kemaman is one of the eight major river systems in the state of Terengganu. Sungai Kemaman is a large river with a total area of about 1800km^2 and 100km of river length. Sungai Kemaman basin is located at the southern part of the state and has a catchment area of about 2, 191km^2. Sungai Kemaman travels eastward through a total of 100km before reaching the sea (Runhill Consulting, 2011). Sungai Kemaman which is one of the rivers faced major flooding on December 2014. During the monsoon season, Sungai Kemaman is associated with heavy rain and high water current, the water will transport a high concentration of suspended and fine sediments to the estuary area (Ismail et al., 2019; Othman et al., 2018).

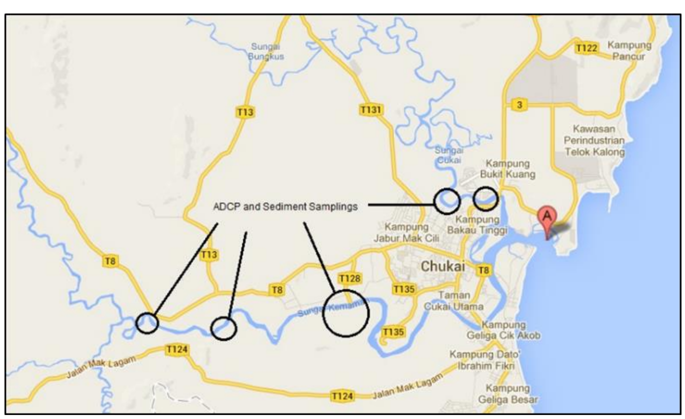

Figure 1: Site location of the study

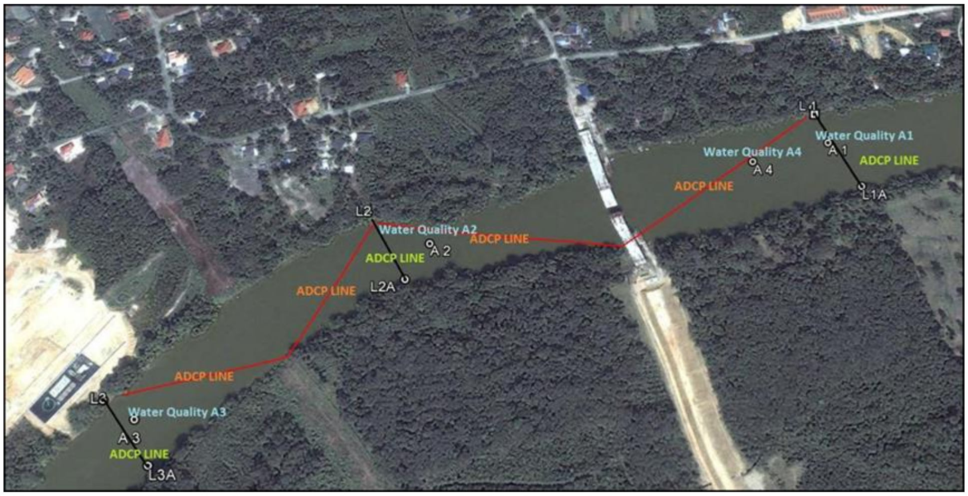

Figure 2: Detail location of ADCP lines and sediment samplings

Data Collection

The primary data has been collected on 20 January 2014 and 19 February 2014. In this study, six cross sectional lines of the Sungai Kemaman had been examined and each of the cross-sectional line with 20 meters apart (Right bank to Left bank: R-LB) the river bed material samples had been collected.

Equipment

There are several mining methods (mechanical or manual) can be used to remove sand from these sources under dry (above water table) and/or wet (above water table) conditions. In this study, primary data was collected by using equipment such as Acoustic Doppler Current Profiler (ADCP) Survey and Helley-Smith sediment sampler. Resistivity Survey is used in determining the availability of potential suitable soil of the study area and the equipment could measure subsurface profile up to 80 meters depth. Meanwhile, Figure 3 illustrated how the Acoustic Doppler Current Profiler is utilized to make river profiler in term of velocity meshes and riverbed depth. It also could measure the total discharge of a particular cross-section. Another equipment, namely Helley-Smith sediment sampler is used to collect bed soil samples and determine sediment transport at the time of sampling. These two methods (ADCP and Helley Smith sediment sampler) could estimate the suitability of available sand material and the flux of sediment transport locally.

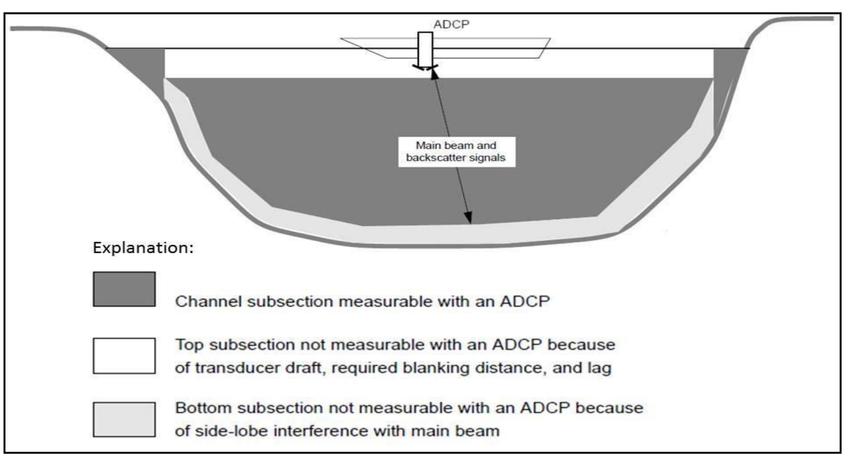

Figure 3: Evaluation of Acoustic Doppler Current Profiler measurements of river discharge

Result and Discussion

Sediment Sampling Analysis

The result of soil characteristics from the Helley-Smith grab sampler are presented in this section. The importance factors to acknowledge are that the period of samples collection was 5 minutes for each sample. The standard Helley-Smith grabber handle is only 2 meters had been extended to 4 meters since Sungai Kemaman has an average depth of more than 3 meters. Since the Sungai Kemaman can be considered deep and its average velocity was more than 0.25 m/s during its normal flow. From all the collected of riverbed materials, the samples trapped in the Helly-Smith grabber were identified that majority of the samples consisted more than 93% of gravel and sand materials as illustrated in Figure 4(a) to Figure 4 (c).

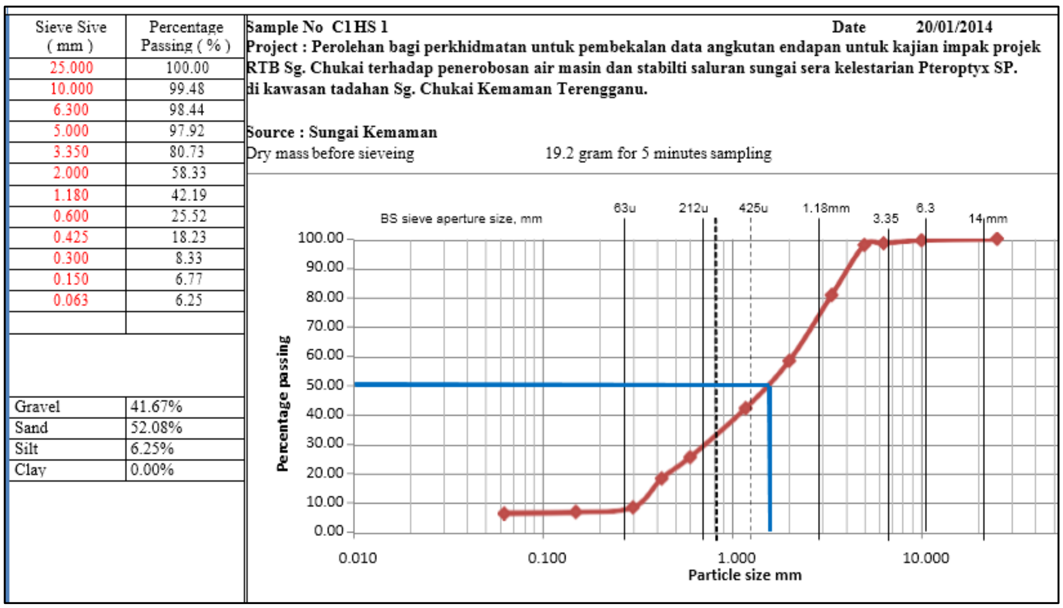

Figure 4 (a). Line 1A R-L Banks; Gravel: 41.67%, **Sand 52.08%,** Silt, 6.25%, Clay 0.00%

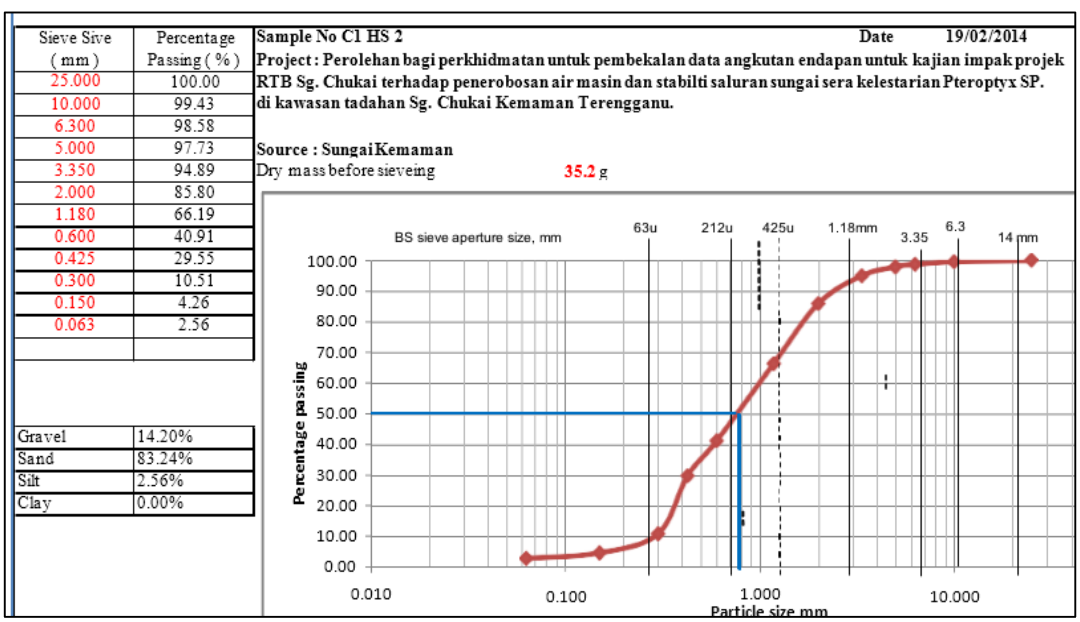

Figure 4 (b). Line 2A R-L Banks; Gravel: 14.20%, **Sand 83.24%**, Silt, 2.56%, Clay 0.00%

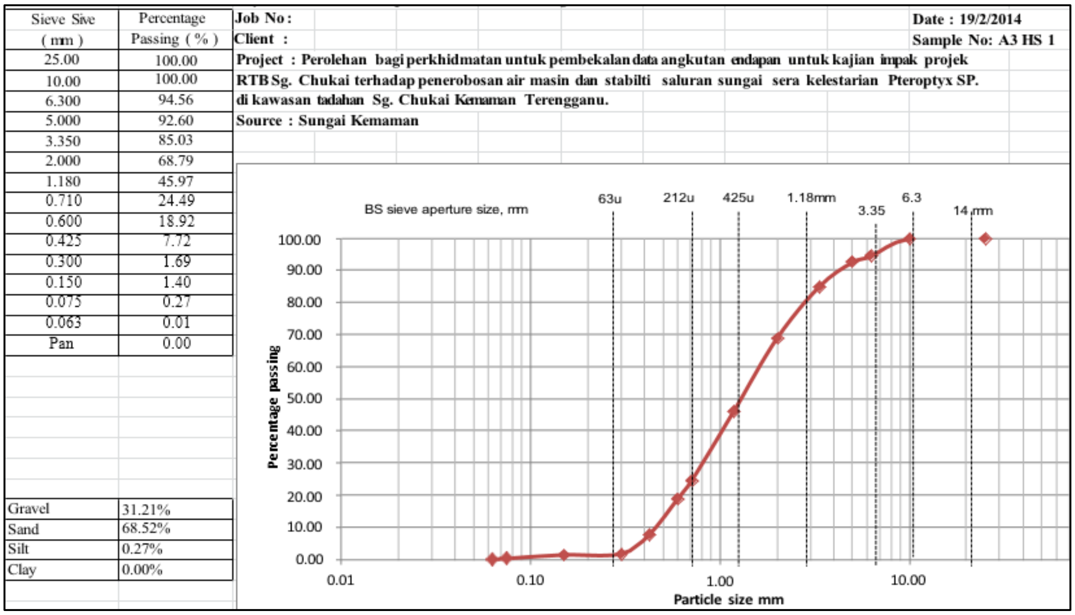

Figure 4 (c). Line 3A R-L Banks; Gravel: 31.21%, **Sand 68.52%,** Silt, 0.27%, Clay 0.00%

Sungai Kemaman Profile

Sungai Kemaman cross section profiles have been produced using ADCP. Six cross sections were selected to obtain the river profile as well as the sediment collection. Figure 5 until Figure 8 showed the locations of cross sections for sediment transport study at Sungai Kemaman. Figure 5 shows the river profile of the river cross section 1A R-LB line. The total measured flow was 82.14m^3/s and the maximum depth of the river is 3.52 meters. The maximum length of the river cross section was 117.58 meters. This figure also shows the locations of the Helley-Smith grabber along the river cross section.

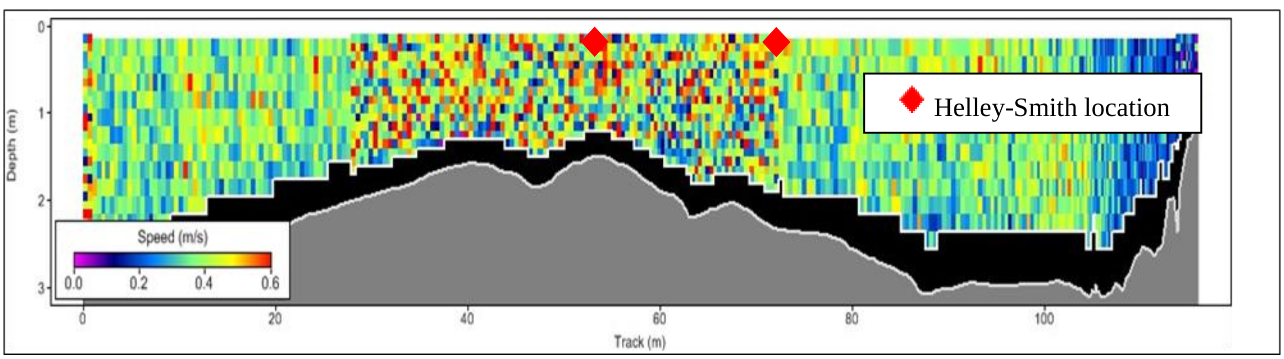

Figure 5: River profile for 1A R-LB, Sungai Kemaman

Next, Figure 6 shows the river profile of the river cross section at section 2A R-LB. The average flow was 83.53m^3/s and maximum depth of the river is 5.57 meters with maximum length of the river cross section was 101.23 meters. Then, Figure 7 shows the river profile at section 2B L-RB with the total flow is 81.34m^3/s and maximum depth of the river is 5.47 meters. The maximum length of the river cross section is 104.64 meters. Based on the results, all details information of velocity and cumulative for the locations of sampling along 1A, 2A R-LB and 2B L-RB has been recorded in Table 1.

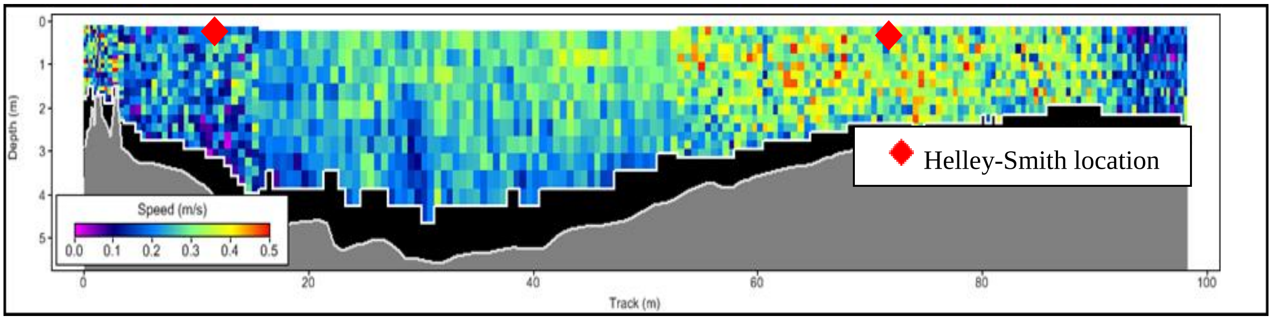

Figure 6: River profile for 2A R-LB, Sungai Kemaman

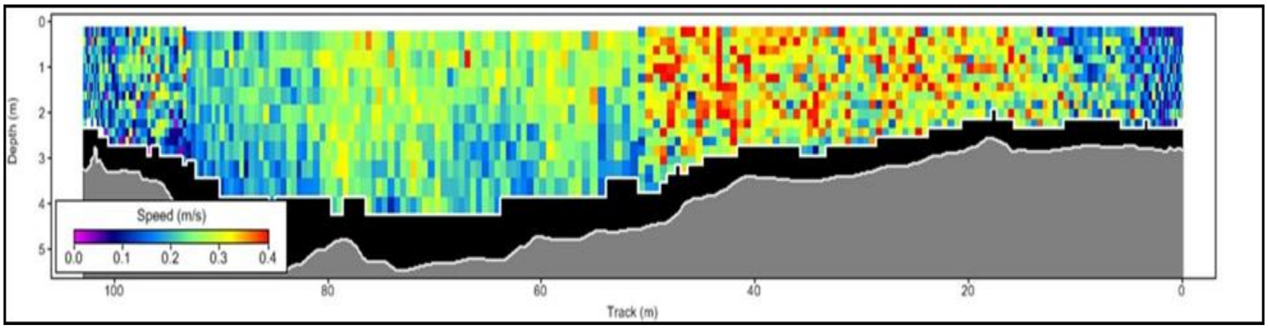

Figure 7: River profile for 2B L-RB, Sungai Kemaman

Table 1: Velocity and cumulative for the locations of sampling along 1A, 2A R-LB and 2B L-RB

Location	1A R-LB		2A R-LB		2B L-RB (R4RB)	
Distance from Left to Right Bank (m)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)
2.3	3.06	0.338				
2.2			2.41	0.122		
2.02					2.84	0.105
20	2.33	0.322	4.60	0.218	2.78	0.250
40	1.57	0.433	5.24	0.230	3.40	0.277
60	1.87	0.274	3.58	0.294	4.74	0.229
80	2.55	0.332	2.82	0.248	4.93	0.252
100	2.98	0.341	2.82	0.156	3.32	0.123

By referring to Figure 8, it shows the river profile of the river cross section for 3A R-LB line. The average flow at this location is 77.63m^3/s, and maximum depth of the river is 5.66 meters. Figure 8 also shows the alignment of the river profile and the maximum length of the river cross section is 105.5 meters. However, Helley-Smith sampling could not be performed at this location due to high water depth (more than 4.0 meters) for the middle span of the river cross-section (Ghani et al., 2011).

Furthermore, Figure 9 shows the river profile of the river cross section 3B L-RB line with the average flow is 75.60m^3/s and maximum depth of the river is 5.70 meters. The maximum length of the river cross section is 106.66 meters. All details information of velocity and cumulative for the locations of sampling along 3A R-LB and 3B L-RB has been recorded in Table 2.

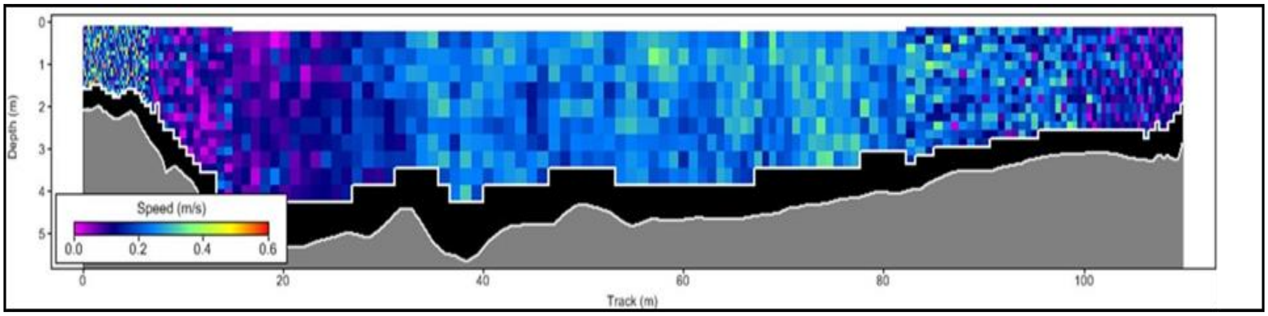

Figure 8: River profile for 3A R-LB Line, Sungai Kemaman

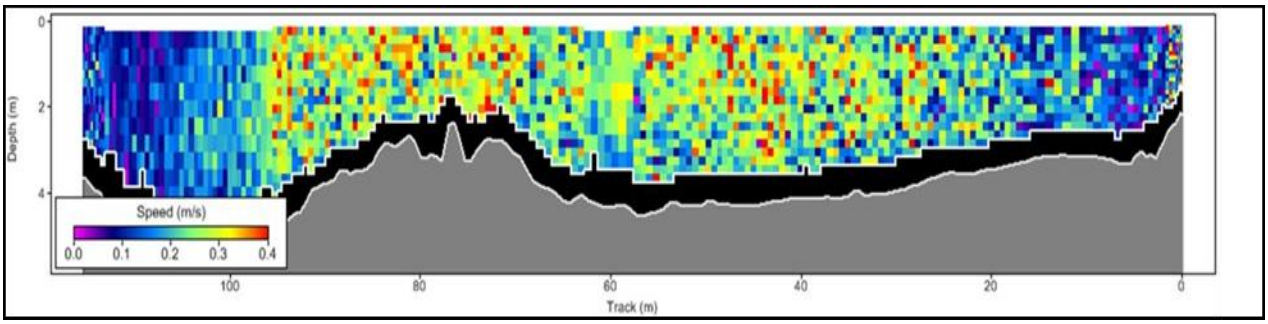

Figure 9: River profile for 3B L-RB line, Sungai Kemaman

Table 2: Velocity and cumulative for the locations of sampling along 3A R-LB and 3B L-RB line

Location	3A R-LB (R5LB)		3B L-RB (R6LB)	
Distance from Left to Right Bank (m)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)
2.01	2.12	0.041		
2.16			2.74	0.023
20	5.31	0.098	3.44	0.150
40	3.47	0.225	4.11	0.234
60	4.64	0.211	4.28	0.238
80	4.00	0.218	3.15	0.232
100	3.11	0.144	5.50	0.167

In summary, majority the score for maximum flow more than 75 m^3/s (volume per second). According to Saleh et al., (2017, 2018), with the maximum flow of the river, it is expected higher the rate of the sediment transport. However, the existence of the river island has disturbed the natural flow of the river. Hence, the extraction of sand at the existing river is proposed. This is because almost 97% of the soil's island consists of fine-grained sand (river sand).

Resistivity Data

The five lines of 2D electrical resistivity surveys were undertaken at the bank of Sungai Kemaman, as shown in Figure 10 and Figure 11. These surveys were intended to identify the sand deposit using 2D ERT as a rapid reconnaissance tool and to extend the knowledge of the electrical properties of sand deposit in this area. By using a 5 meter (L1, L2, L4) and 3 meter electrode spacing (L3) with 36 electrodes, the depth of investigation achieved for all the models were around 25 to 35 meter. The depth of investigations can be improved significantly by using longer survey alignment or other array types such as pole-dipole (with the used of remote electrode).

However, due to the constraint of area at the site, the survey alignment had been restricted to only about 175 meters (L1, L2, and L4) and 105 meters for L3. The most distinctive features obtained from the electrical resistivity survey are the extensive zone of high resistivity value beginning at ground level for all models to about 4 meters elevation while below 4meters elevation shows the low resistivity.

Figure 10: Location of the electrical resistivity survey lines along the bank of Sungai Kemaman

Figure 11: Location of the electrical resistivity survey lines along the bank of Sungai Kemaman

In all cases (refer Figure 12 to Figure 16) the 2D electrical resistivity survey was successful in imaging the thickness of the sand due to the good resistivity contrast between the sand and other earth materials at the site. The resistivity contour value is adjusted based on geological information that fit the resistivity range with different colours.

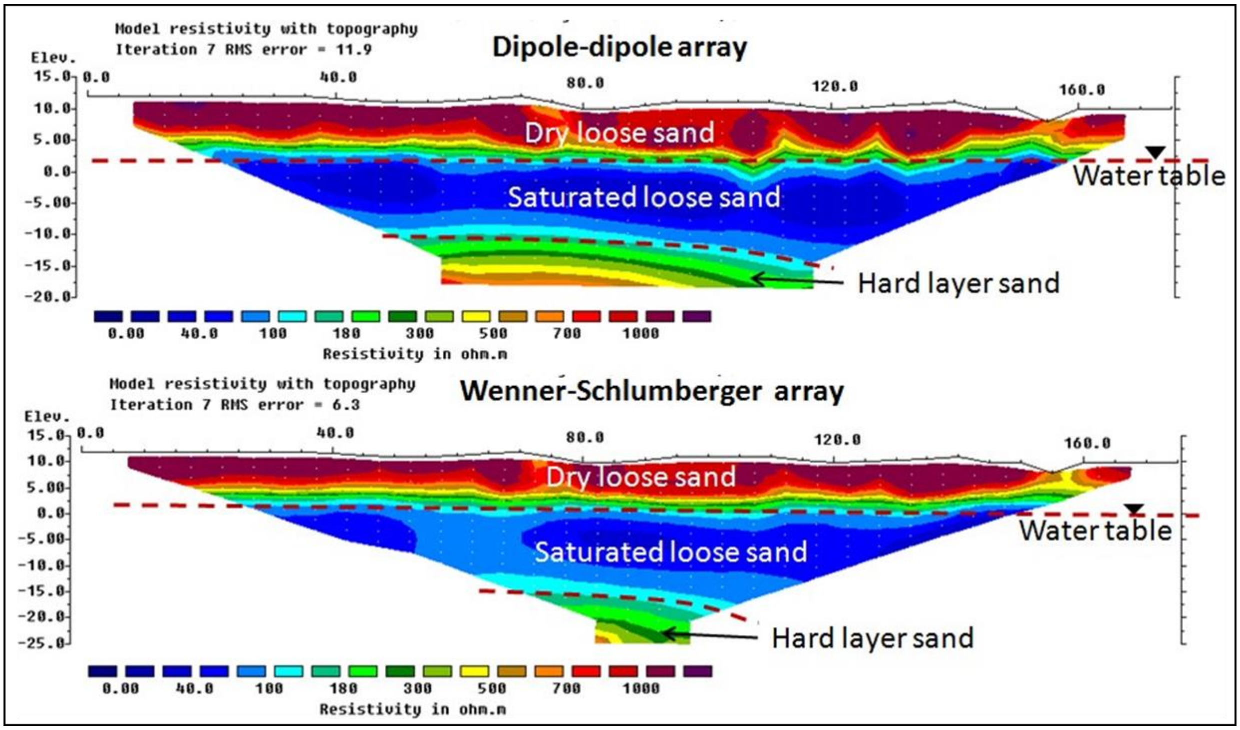

Figure 12. Electrical resistivity survey result for Line 1 (L1-Right Bank), Sungai Kemaman

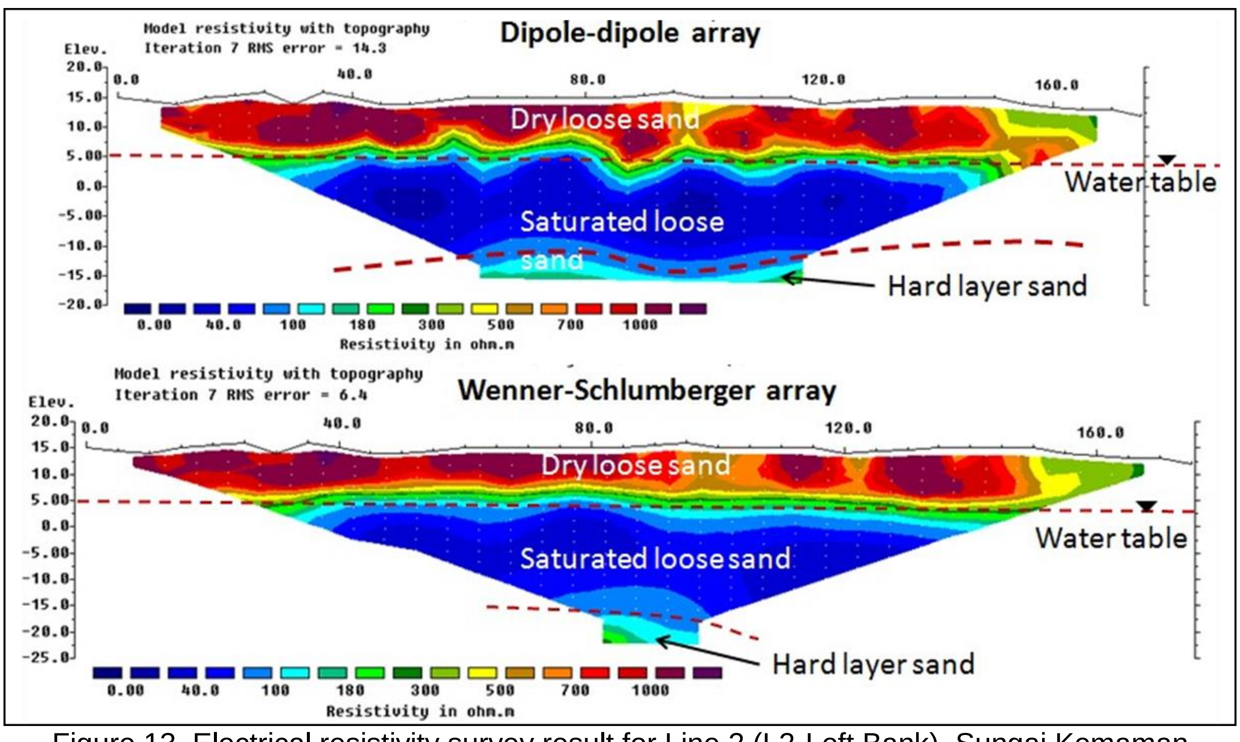

Figure 13. Electrical resistivity survey result for Line 2 (L2-Left Bank), Sungai Kemaman

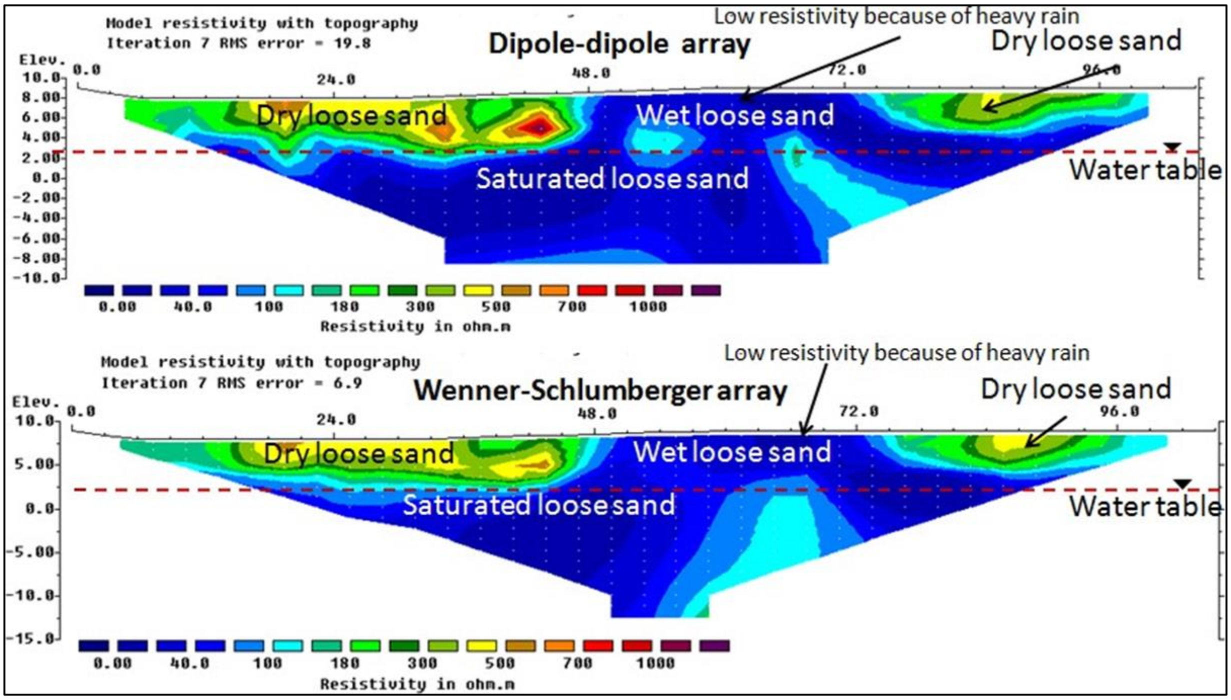

Figure 14: Electrical resistivity survey result for Line 3 (L3-Right Bank), Sungai Kemaman

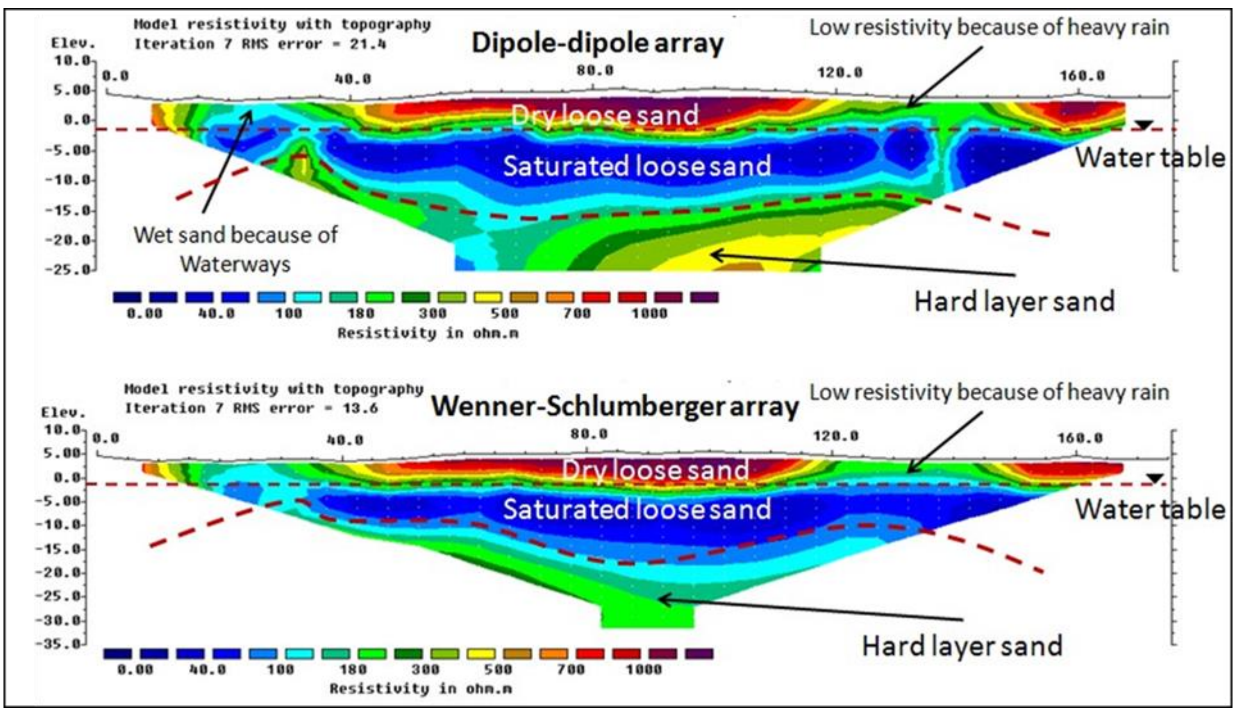

Figure 15: Electrical resistivity survey result for Line 4 (L4-Left Bank), Sungai Kemaman

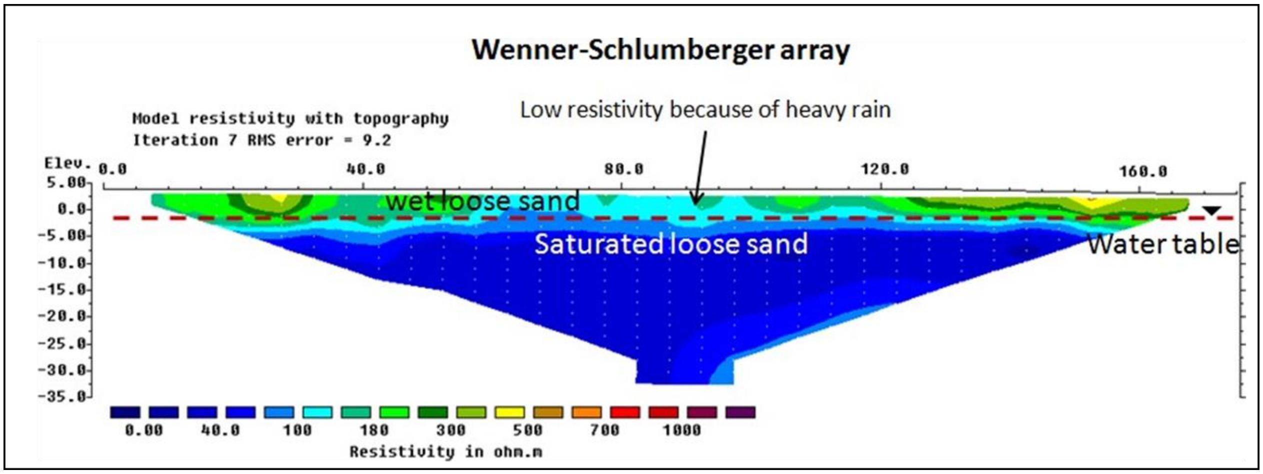

Figure 16: Electrical resistivity survey result for Line 5 (L5-Left Bank), Sungai Kemaman

This finding had indicated that the sand deposits are highly to fully saturated with water below 4 meters for all models. From the finding, a substantial thickness of sand overburden was successfully identified in the resistivity image as a sandy resistivity zone which is between 60-1000 ohm-m. Thin layer from the ground surface about 5 to 7 meters depth with high resistivity value as indicated in model L1, L2 and L4 (red to orange color indicated in the legend) is probably the layer consist of fill materials with dry condition in the range of resistivity value from 400 ohm-m to more than 1500 ohm-m. The high resistivity value is also probably indicating the high noise level of the data set because of dry material especially at the upper part of the model.

From the electrical resistivity survey findings, the sand deposit at Sungai Kemaman represents a relatively simple geology which consists of sandstone/ shale at deeper part of the model (which is undetectable using the electrical resistivity survey due to the depth of investigation about 35 m), overlain by recent sediment mainly sand materials (60-1000 ohm-m) (Table 3). Basically, the resistivity value of alluvium is in the range between 10-800 ohm-m.

Table 3: Resistivity value with the expected earth materials at the site

Material	Resistivity (ohm-m)
Alluvium	10 to 800
Sand	60 to 1000
Clay	1 to 100
Groundwater (fresh)	10 to 100
Sandstone	$8 – 4 \times 10^3$

Conclusion

This study has approved that Sungai Kemaman is the most potential and suitable of the sand mining area in the Kemaman River Basin, Terengganu. Even though floodplain or riverbed sand mining has been considered a better choice than the direct extracting of sand from the river, significant threats to the sustainability of the river and to the protection of the river still need to continue. In fact, sand mining can lead to changes in the riparian climate, both locally and distant to the mining site, either in the short or long term. In addition to controlling future extractions, the system must consider the environmental problems in the existing mines and illegal mining activities.

Future research work is needed to improve this system, which is likely to include targeted and accurate reporting for improvements to the planning regime or other regulatory changes. In order to achieve a robust and effective program, it would be important to collaborate closely with the local government and other natural resource managers.

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